CM3215 MichiganTech

Fundamentals of Chemical Engineering Laboratory

Pumping Performance

Professor Faith Morrison

Department of Chemical Engineering
Michigan Technological University

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There are two parts to pump performance:

Demand

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Pumping System Curves

Professor Faith Morrison
Department of Chemical Engineering
Michigan Technological University

Today

Supply

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Analysis of a Centrifugal Pump: Pumping Head Curves

Professor Faith Morrison
Department of Chemical Engineering
Michigan Technological University

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Analysis of a Centrifugal Pump: Pumping Head Curves

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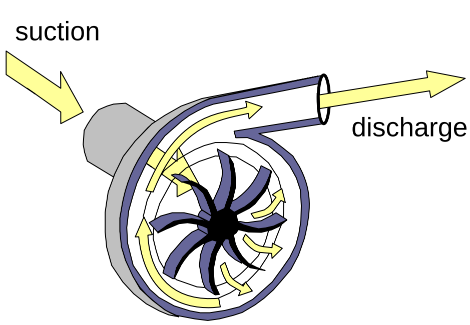
Michigan Technological University

Reference: Morrison, *An Introduction to Fluid Mechanics*, Section 9.2.4.

Centrifugal Pumps

- Centrifugal force is used to fling fluid from the suction side to the discharge
- Centrifugal pumps put out **neither** constant flow rate **nor** constant pressure
- We must use the mechanical energy balance to figure out how a centrifugal pump will perform in a given situation



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System Curve Assignment (week 8; was due week 10)

How do you choose a centrifugal pump for a given duty?

- Calculate the flow-rate-dependent **demands** of a system = **system head curve** (this assignment)
- Compare the system-head curve (demands) to the available pumping-head curve (**supply**), and choose the right pump

Pumping Head Lab (week 12)

- Pumping Head Characteristic Curves are plots of what an existing pump can do under various loads (duties)
- We measure a pump's characteristic curve by determining $\Delta p = p_{discharge} - p_{suction}$ on the suction/discharge system

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System Curve Assignment (week 8; was due week 10)

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Took the role of the user

Pumping Head Lab (week 12)

- Pumping Head Charact
an existing pump can do under various
- We measure a pump's characte curve by determining $\Delta p = p_{discharge} - p_{suction}$ on the suction/discharge system

Assignment 6:
Prepare to choose a pump for a system

Was due Week 10

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System Curve Assignment (week 8; was due week 10)

How do you choose a centrifugal pump for a given duty?

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Tuesday

Take the role of the manufacturer

Pumping Head Lab (week 12)

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WEEK 12

Report 6: Characterize a laboratory pump

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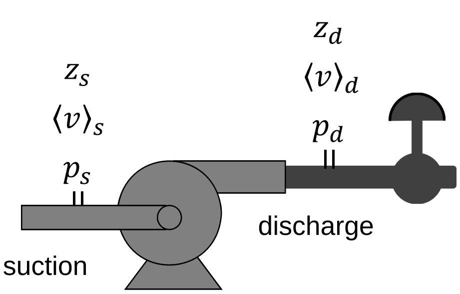
Take the role of the manufacturer

To report the performance of a centrifugal pump, we apply the Mechanical Energy Balance around the pump to see what we need to measure.

$$\frac{\Delta p}{\rho g} + \frac{\Delta \langle v \rangle^2}{2g\alpha} + \Delta z + \frac{F_{friction}}{g} = \frac{W_{s,on}}{\dot{m}g}$$



This is called the "suction-discharge" system.

Take the role of the manufacturer

Centrifugal Pumps - MEB written on suction/discharge system

$$\frac{p_d - p_s}{\rho g} + \frac{\langle v\rangle_d^2 - \langle v\rangle_s^2}{2g\alpha} + (z_d - z_s) + \frac{F_{d,s}}{g} = \frac{W_{s,on,d\rightarrow s}}{\dot{m}g}$$

$$\frac{p_d - p_s}{\rho g} + \frac{\langle v\rangle_d^2 - \langle v\rangle_s^2}{2g\alpha} + (z_d - z_s) = \frac{W_{s,on,d\rightarrow s}}{\dot{m}g} - \frac{F_{d,s}}{g}$$

Losses *inside* pump reduce the usable work

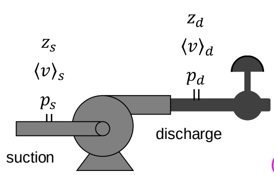
pump efficiency

$$\equiv \frac{\eta W_{s,on,d\rightarrow s}}{\dot{m}g}$$

$0 \le \eta \le 1$

$\eta W_{s,on,d\rightarrow s}$ = usable work

brake horsepower



(In U.O. lab senior year, you will measure a pump efficiency, η)

Take the role of the manufacturer

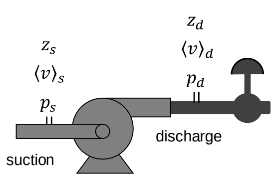
Centrifugal Pumps - MEB written on suction/discharge system

Measuring these quantities on suction-discharge system

$$\frac{p_d - p_s}{\rho g} + \frac{\langle v\rangle_d^2 - \langle v\rangle_s^2}{2g\alpha} + (z_d - z_s) = \left(\frac{W_{s,on,ds}}{\dot{m}g} - \frac{F_{d,s}}{g}\right)$$

$$= \frac{\eta W_{s,on,ds}}{\dot{m}g}$$

Tells us about the net capability of the pump



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Take the role of the manufacturer

Measuring the Pumping Head curve:

- Write the MEB on the suction-discharge system
- Measure pressures, velocities, elevations at (d) and (s)
- Pump friction is moved to the RHS and combined with the work, leaving H_p as usable (delivered) head; we do not need to measure pump friction (unless measuring efficiency, η)

$$\frac{p_d - p_s}{\rho g} + \frac{\langle v\rangle_d^2 - \langle v\rangle_s^2}{2g\alpha} + (z_d - z_s) = \left(\frac{W_{s,on,ds}}{\dot{m}g} - \frac{F_{d,s}}{g}\right) \equiv H_p$$

$$H_p \equiv \frac{p_d - p_s}{\rho g} + \frac{\langle v\rangle_d^2 - \langle v\rangle_s^2}{2g\alpha} + (z_d - z_s)$$

Total head $= \left(\frac{\text{energy}}{\text{weight}}\right)$

H_p is a function of flow rate (through the average velocity and $p_d(Q)$, $p_s(Q)$).

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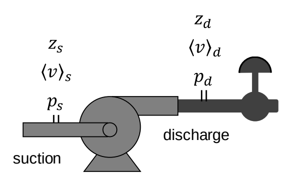
Take the role of the manufacturer

Measuring the Pumping Head curve:

$$H_p \equiv \frac{p_d - p_s}{\rho g} + \frac{\langle v\rangle_d^2 - \langle v\rangle_s^2}{2g\alpha} + (z_d - z_s)$$

- Operate pump
- Vary flow rate with metering valve on discharge side
- Calculate H_p from measured Q, p_d, p_s, z_d, z_s

$Q(gpm)$	$p_d(psig)$	$p_s(psig)$
1.0	27.1	-1.0
1.2	26.4	-0.5
1.8	25.2	1.1
2.1	24.0	1.2
…	…	…



Suction pressures can drop below atmospheric

Total head $= \left(\frac{\text{energy}}{\text{weight}}\right)$

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Take the role of the manufacturer

Measuring the Pumping Head curve:

$$H_p \equiv \frac{p_d - p_s}{\rho g} + \frac{\langle v \rangle_d^2 - \langle v \rangle_s^2}{2g\alpha} + (z_d - z_s)$$

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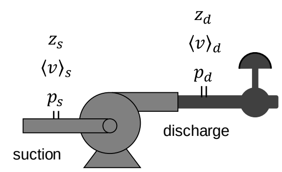

Choice of Q's to measure pressures at is up to you; **be sure to address all your objectives**

Suction pressures can drop below atmospheric

Total head $= \left(\frac{\text{energy}}{\text{weight}}\right)$

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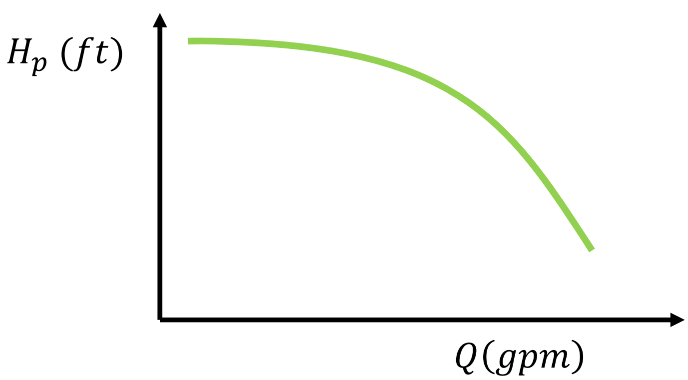
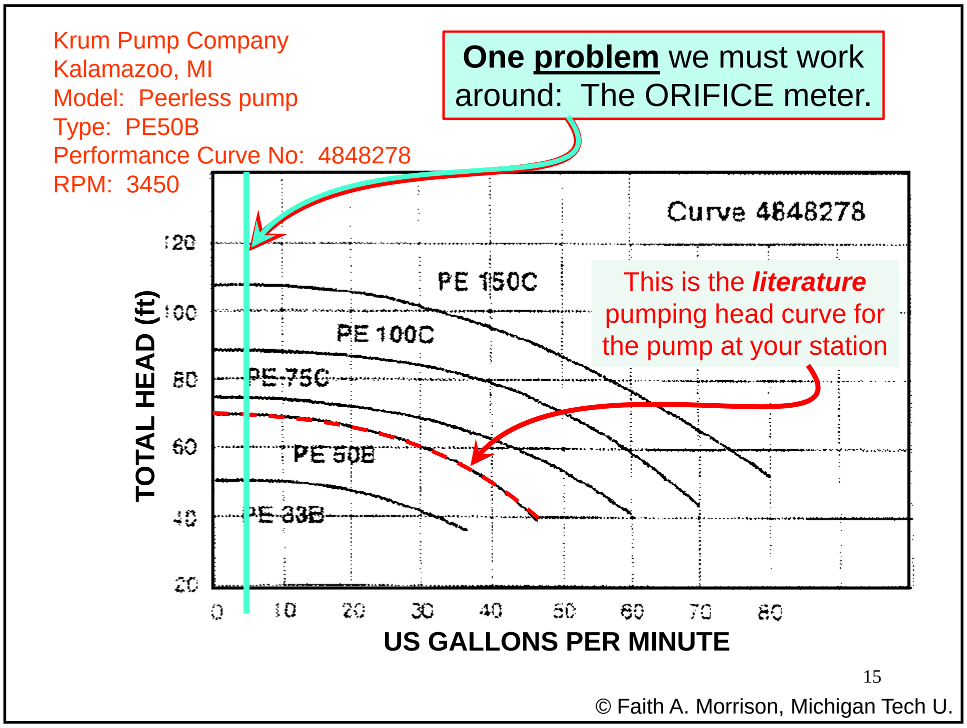
Take the role of the manufacturer

- Plot results as a function of Q

Pumping Head - pump characteristic curve




Krum Pump Company
Kalamazoo, MI
Model: Peerless pump
Type: PE50B
Performance Curve No: 4848278
RPM: 3450
One problem we must work around: The ORIFICE meter.
Curve 4848278
PE 150C
PE 100C
PE 75C
PE 50B
PE 33B
This is the literature pumping head curve for the pump at your station
TOTAL HEAD (ft)
120
100
80
60
40
20
0
10
20
30
40
50
60
70
80
US GALLONS PER MINUTE
15
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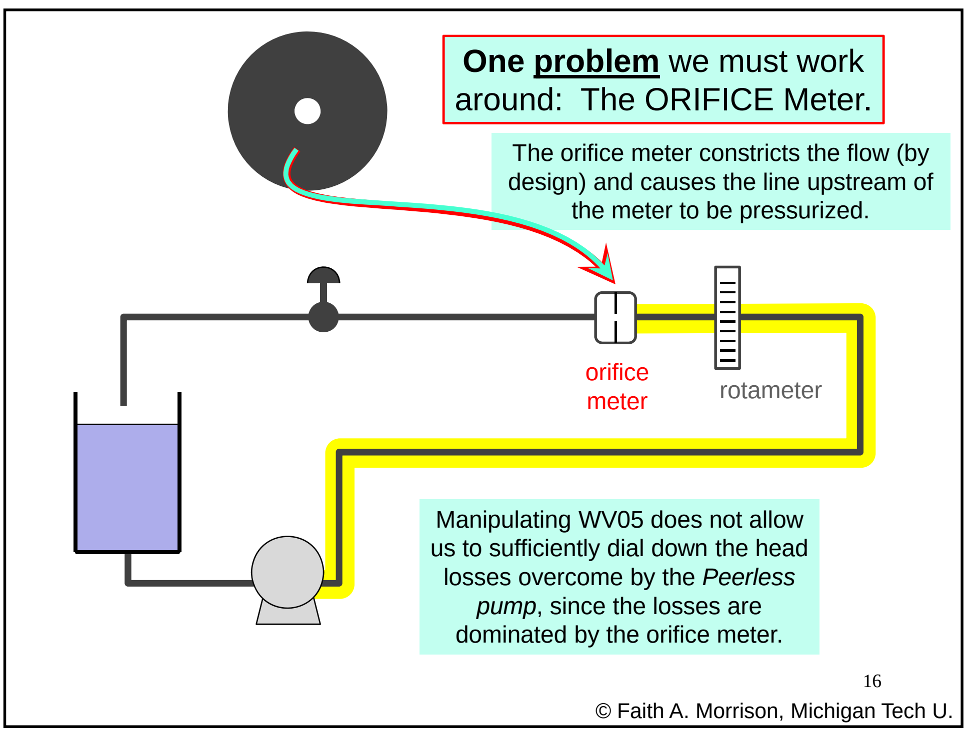
One problem we must work around: The ORIFICE Meter.
The orifice meter constricts the flow (by design) and causes the line upstream of the meter to be pressurized.
orifice meter
rotameter
Manipulating WV05 does not allow us to sufficiently dial down the head losses overcome by the Peerless pump, since the losses are dominated by the orifice meter.
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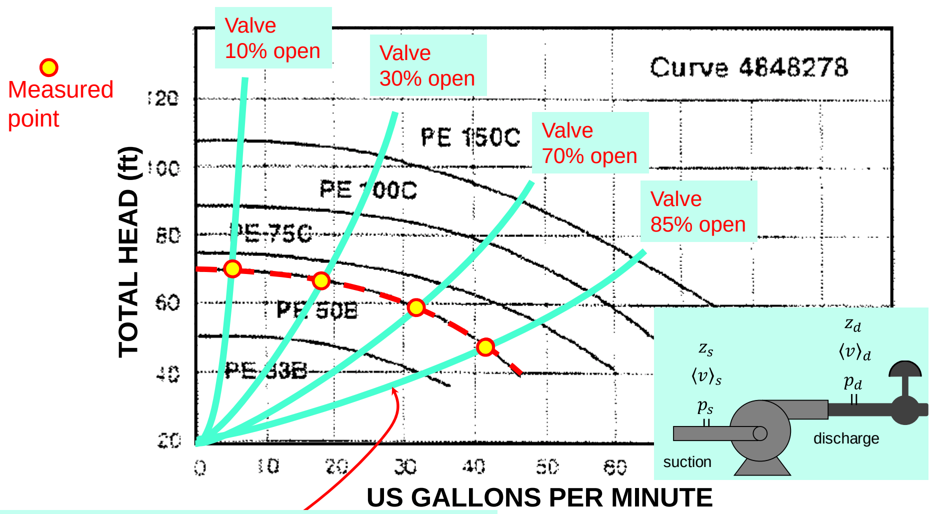
Normally, with the head loss dominated by the post-pump metering valve, we can open the valve to dial down losses, and shift the operating point for data acquisition on the suction-discharge system.



(System curves the pump is pumping against; they shift to the right as metering valve opens)

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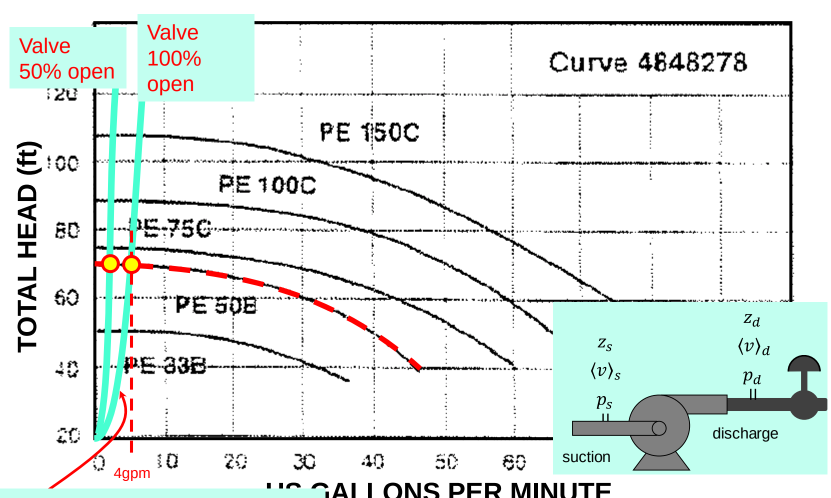
The orifice meter dominates the downstream head loss in our CM3215 lab stations. Without removing the orifice meter, we cannot explore the full range of the Krum Peerless pump.



(System curves the pump is pumping against; includes orifice meter)

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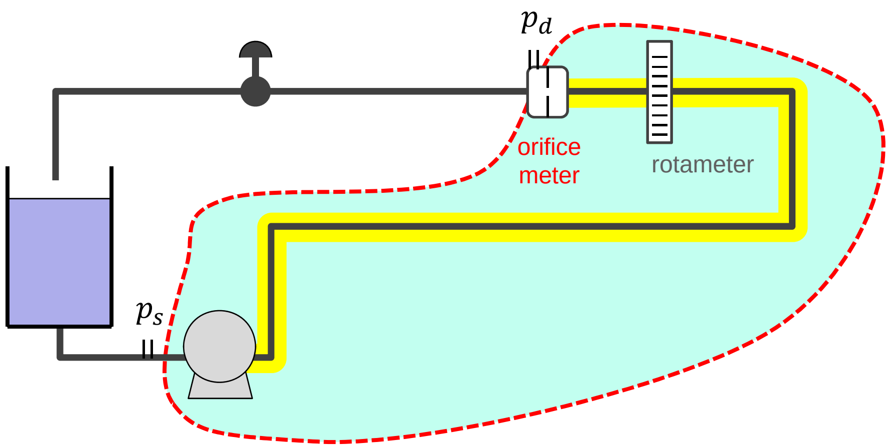
Solution: Define everything between the Krum suction and the orifice meter discharge as a new, "*Lossy*®" pump

Characterize the *Lossy* ® *pump* instead of the Krum Peerless pump.



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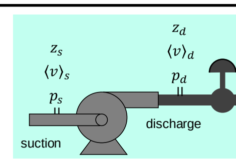
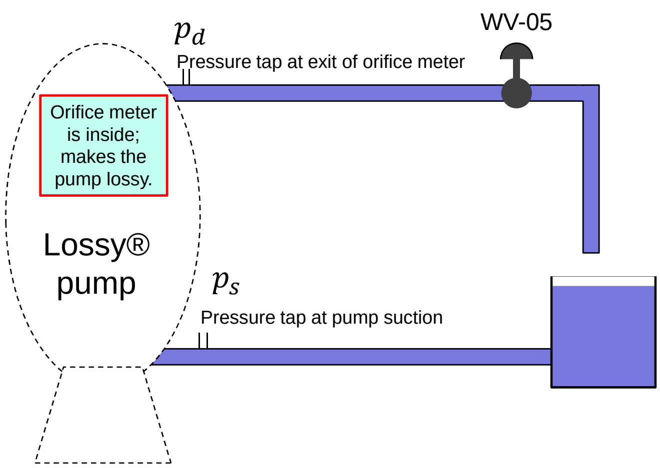


The Solution: **The CM3215 "Lossy®" Pump**

•Extends from the pump suction to the exit of the orifice meter.



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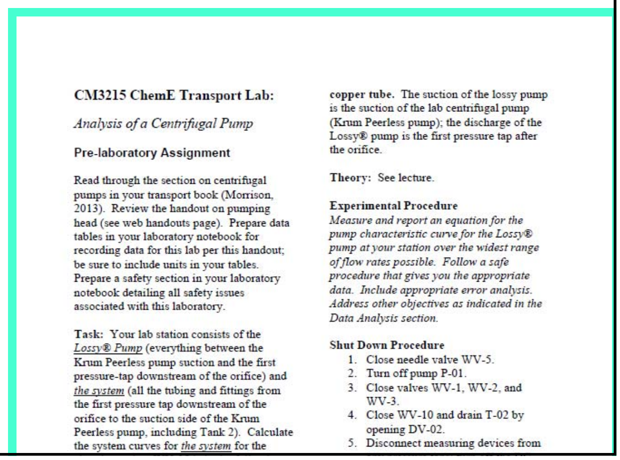
Report 6: Characterize the Lossy® Pump

- Determine the pump characteristic curve for your lab station's Lossy ® pump (suction at Krum Peerless pump suction, discharge at orifice exit).
- Measure the Lossy® pump operating conditions for when the throttling valve WV-05 is 0.5 turn, 1.0 turns, and 2 turns open.
- Predict the operating conditions for the Lossy® pump when it operates against the lab station's system with WV-05 0.5 turn, 1.0 turns, and 2 turns open.
- Quantitatively compare your predictions and observations (use appropriate error analysis).
- Address all objectives assigned.



CM3215 ChemE Transport Lab:

Analysis of a Centrifugal Pump

Pre-laboratory Assignment

Read through the section on centrifugal pumps in your transport book (Morrison, 2013). Review the handout on pumping head (see web handouts page). Prepare data tables in your laboratory notebook for recording data for this lab per this handout; be sure to include units in your tables. Prepare a safety section in your laboratory notebook detailing all safety issues associated with this laboratory.

Task: Your lab station consists of the *Lossy® Pump* (everything between the Krum Peerless pump suction and the first pressure-tap downstream of the orifice) and *the system* (all the tubing and fittings from the first pressure tap downstream of the orifice to the suction side of the Krum Peerless pump, including Tank 2). Calculate the system curves for *the system* for the

copper tube. The suction of the lossy pump is the suction of the lab centrifugal pump (Krum Peerless pump); the discharge of the Lossy® pump is the first pressure tap after the orifice.

Theory: See lecture.

Experimental Procedure
Measure and report an equation for the pump characteristic curve for the Lossy® pump at your station over the widest range of flow rates possible. Follow a safe procedure that gives you the appropriate data. Include appropriate error analysis. Address other objectives as indicated in the Data Analysis section.

Shut Down Procedure
1. Close needle valve WV-5.
2. Turn off pump P-01.
3. Close valves WV-1, WV-2, and WV-3.
4. Close WV-10 and drain T-02 by opening DV-02.
5. Disconnect measuring devices from

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Prelab assignment

Tasks:

Your lab station consists of the *Lossy® Pump* (everything between the Krum pump suction and the first pressure-tap downstream of the orifice), and …

The system (all the tubing and fittings from the first pressure tap downstream of the orifice to the suction side of the Krum Peerless pump, including the flow exit and Tank 2).

Using the system curves for *the system* for the situations when WV-05 is in the following three states:

- 0.5 turn open (180°), 1 turn open (360°), 2 turns open (fittings and tube lengths given in Assignment 6).

answer this question: What head needs to be supplied by a pump to produce 1 gpm for each of these three configurations of *the system*?

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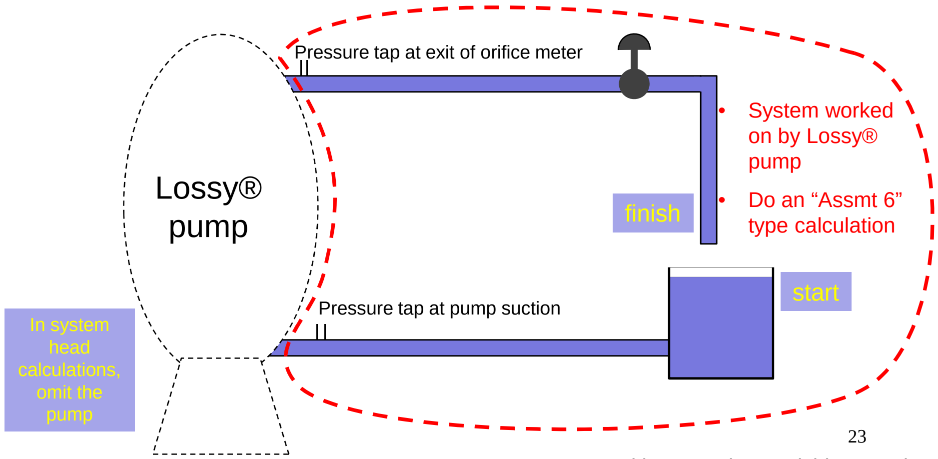
The CM3215 "Lossy®" Pump

•Extends from the pump suction to the exit of the orifice meter.

•The system on which this pump operates, thus, is the piping and fittings between the exit of the orifice meter and the pump suction



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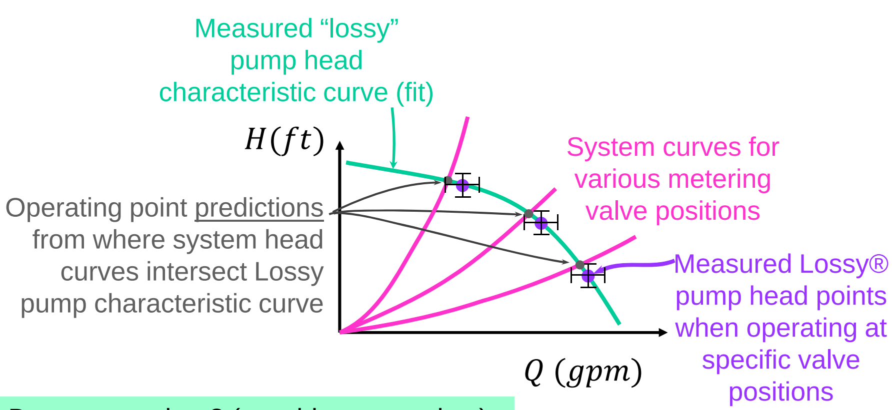
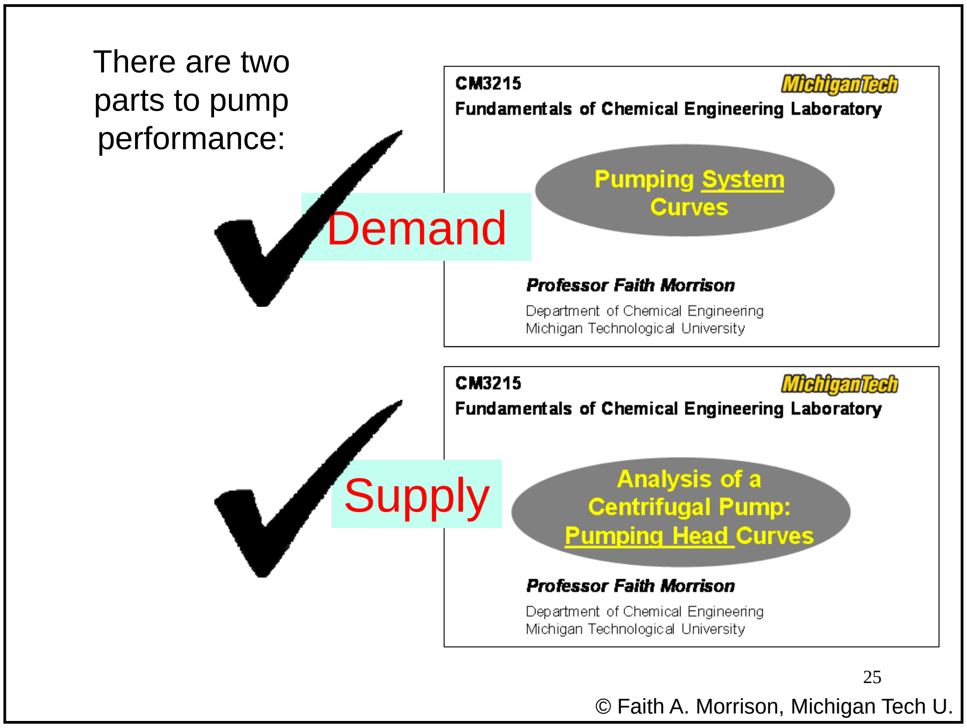
"Predict the operating conditions for the Lossy® pump when it operates against the lab station's system with WV-05 0.5 turn, 1.0 turns, and 2 turns open."



Does •, match • ? (consider uncertainty)

How well do we know the system curves?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